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RESEARCH MEMORANDUM

TIME HISTORIES OF HORIZONTAL-TAIL LOADS, ELEVATOR LOADS,

AND DEFORMATIONS ON A JET-POWERED BOMBER AIRPLANE

DURING WIND-UP TURNS AT APPROXIMATELY

15,000 FEET AND 22,500 FEET

By William A. McGowan

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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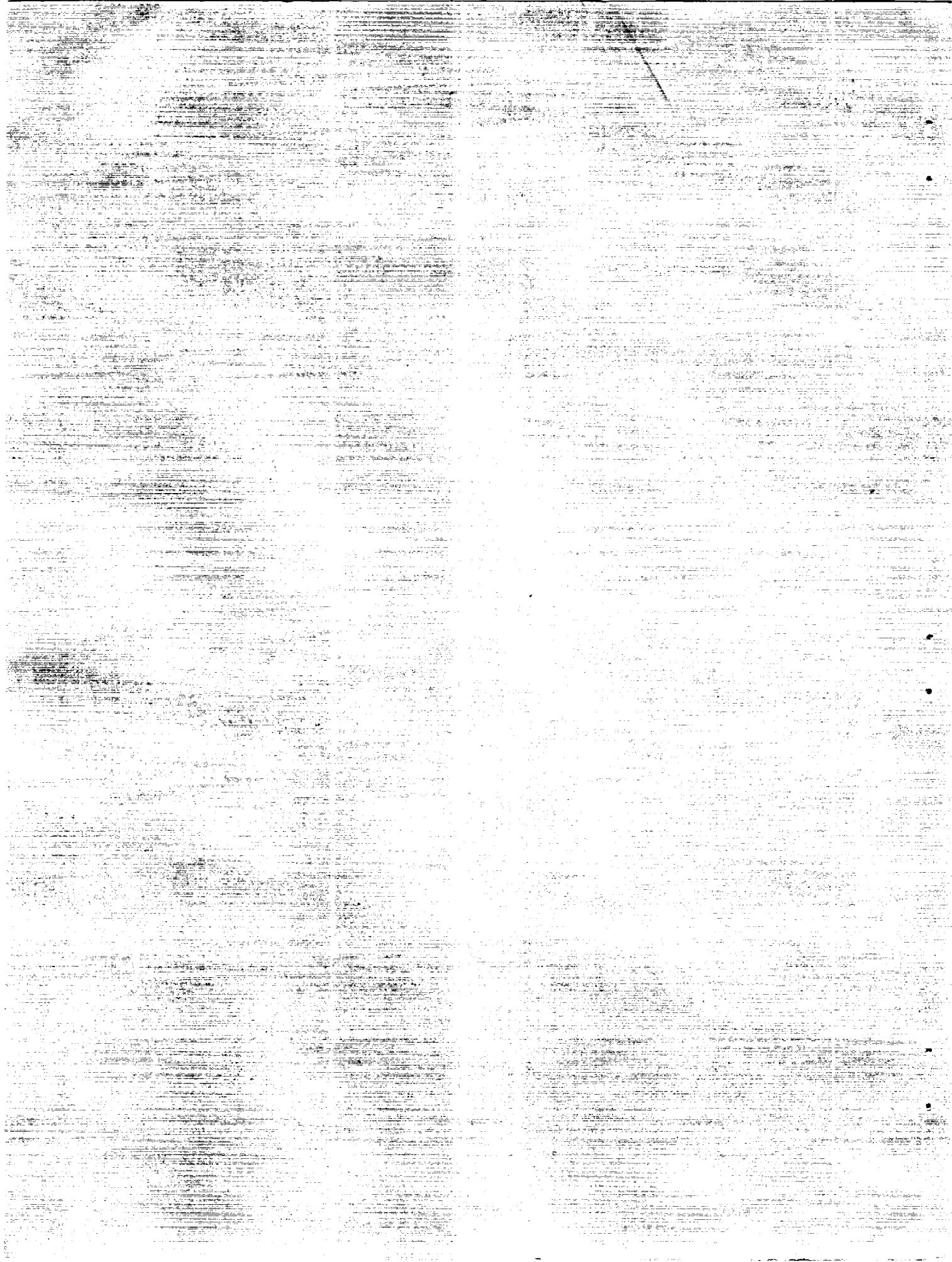
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SUMMARY

Time histories are presented of horizontal-tail loads, elevator loads, and deformations on a jet-powered bomber airplane during wind-up turns at pressure altitudes of approximately 15,000 feet and 22,500 feet. The normal accelerations experienced varied from 0.9g to 2.9g at Mach numbers from 0.36 to 0.75. The maximum horizontal-tail and elevator loads measured were approximately 11,900 pounds and 900 pounds, respectively. Elevator twists varied to 1.8° and stabilizer twists were small. The greatest fuselage deflection was about 1.9 inches.

INTRODUCTION

The NACA is currently conducting a flight investigation to determine the loads and deformations on a jet-bomber type of airplane. These results may be used to check the accuracy of available methods of computing loads on the horizontal tail and the accuracy of the aerodynamic-center location and zero-lift pitching moment of the wing-fuselage combination as determined from small-scale wind-tunnel measurements. For this investigation a B-45A airplane has been instrumented with strain-gage bridges for measurements of the loads on the horizontal tail, vertical tail, and the wing and, with additional instruments, for measurements of the elevator and stabilizer twist and fuselage deflection.

Time histories of aerodynamic loads and deformations for the B-45A airplane during level flight, aileron rolls, pull-ups, and turns have been presented in references 1 to 4. This paper presents time histories of horizontal-tail loads, elevator loads, stabilizer and elevator twists, and fuselage deflections during further wind-up turns at pressure altitudes of approximately 22,500 feet and 15,000 feet.

INSTRUMENTATION

A three-view drawing of the test airplane, with approximate locations of strain-gage bridges and deflection-measuring devices, is given in figure 1.

Standard NACA recording instruments were used to measure airspeed, altitude, rolling, pitching, and yawing velocities, sideslip angle, control forces and positions, and accelerations. NACA optical-recording three-component accelerometers were mounted at the airplane center of gravity and at the approximate quarter-chord station of the horizontal tail at the airplane center line.

Two booms, one at each wing tip, extending approximately 1 local chord length ahead of the leading edge contained the airspeed head and the sideslip-angle transmitter. The results of a flight calibration of the airspeed system for position error and an analysis of available data for a similar installation indicated a Mach number error of less than ±0.01 throughout the test range.

Electrical resistance strain-gage bridges were mounted on each spar near the root on both sides of the horizontal tail to measure shear and bending moment. Strain-gage bridges were also mounted on the elevator torque tube and hinge brackets to measure torque and total elevator load, respectively.

Twist bars were installed in the horizontal stabilizers to measure stabilizer twist at the tip and midsemispan stations with respect to the stabilizer root. Control-position transmitters were installed at the tip and root of the elevators and wired electrically to measure elevator twist relative to the stabilizer. The positions of the rudder, ailerons, elevators, and elevator trim tabs were measured at the inboard ends by control-position transmitters.

An optigraph mounted within the fuselage at the rear spar of the wing continuously recorded the motion of small concentrated light sources positioned in the fuselage at the front and rear spars of the horizontal tail. An additional optical arrangement was used to measure the distortion of the optigraph mount with respect to the datum position. (Distortion of the optigraph mount was not considered in determining the fuselage-deflection data presented in references 1 and 2.) From this installation a time history of the structural deflection of the rear portion of the fuselage with respect to the wing rear spar was obtained.

The output from the strain-gage bridges and twist-measuring devices was recorded on two 18-channel oscillographs. A 0.1-second time pulse was used to correlate the records of all recording instruments.

RESULTS AND DISCUSSION

Aerodynamic loads and the resulting structural twists of the horizontal tail and elevators as well as the fuselage deflection were determined for the B-45A airplane during 17 power-on wind-up turns. Time histories of the aerodynamic loads, twists, and fuselage deflection in addition to elevator angle, airplane normal-force coefficient, and normal acceleration at the center of gravity are presented in figures 2 to 18. In figures 19 to 22, 1 g values of the horizontal-tail aerodynamic load, elevator dissymmetry load, and stabilizer twists are plotted against Mach number for the two test altitudes. The 1 g fuselage-deflection variation with respect to the horizontal tail load is shown in figure 23. A summary of pertinent flight conditions for the runs illustrated in the figures is given in table I. Aerodynamic tail loads were determined by adding the inertia loads to the structural loads measured by the strain-gage bridges. The airplane was trimmed in the clean condition at the start of each run.

The estimated accuracies of the aerodynamic loads, twists, fuselage deflection, and parameters are as follows:

Center-of-gravity normal acceleration, g units . . . . ±0.03
Total horizontal-tail aerodynamic load, lb . . . . ±160
Each elevator aerodynamic load, lb . . . . ±60
Elevator angle, deg . . . . ±0.25
Elevator twist (relative to stabilizer), deg . . . . ±0.07
Stabilizer twist at midsemispan, deg . . . . ±0.007
Stabilizer twist at tip, deg . . . . ±0.015
Mach number . . . . ±0.01
Fuselage deflection, in. . . . . ±0.04

Fuselage-deflection records were not available for the last part of the maneuvers represented by figures 15 to 17 or for the entire maneuver illustrated by figure 18.

Total tail loads.- The maximum up tail load (fig. 4) measured was 5,400 pounds and occurred at a Mach number of 0.57 at a pressure altitude of 21,900 feet when the normal acceleration was 2.9g. The maximum down load (fig. 18) measured was 11,900 pounds and occurred at a Mach number of 0.73 at a pressure altitude of 14,400 feet and a normal acceleration of 1 g.

The tail loads at 1 g (fig. 19) become greater in the down direction with increasing speed. Changes in tail load are also partially attributed to changes in airplane weight and center-of-gravity position. At a pressure altitude of about 15,000 feet the down tail load for trim at 1 g varied from 2,100 pounds to 11,800 pounds for a Mach number

variation of 0.51 to 0.73. At a pressure altitude close to 22,500 feet
the tail load for trim at 1 g varied from 1,700 pounds up to 8,200 pounds
down for a Mach number variation of 0.36 to 0.75.

Figures 2 to 18 show that the total-tail-load increment per g
increases with the higher values of airplane normal acceleration, this
increase indicating a forward travel of the wing-fuselage aerodynamic
center.

The tail-load dissymmetry was small in all runs illustrated in the
figures.

Elevator loads and elevator positions.- At the start of each wind-
up turn, when the normal acceleration was close to 1 g, up elevator
loads were encountered. However, as the run progressed, the elevator
loads increased in the down direction. The maximum up loads (figs. 16
to 18) were about 900 pounds and occurred on the left elevator during
the three runs made at pressure altitudes close to 15,000 feet at a
Mach number range of 0.68 to 0.73. The maximum down load (fig. 4) of
760 pounds occurred on the left elevator at a Mach number of $0.57g$
and $2.75g$ normal acceleration.

The greatest elevator-load dissymmetry (fig. 18), left-elevator
load minus right-elevator load, experienced was about 500 pounds. The
dissymmetry at 1 g (fig. 20) generally became more positive with an
increase in Mach number.

The left-elevator position at the root was more down than the
right-elevator position during these maneuvers with a maximum measured
difference of about $1.0°$.

Stabilizer and elevator twist.- The stabilizer tip and midsemispan
twists increased leading edge up with increasing normal acceleration.
At a normal acceleration of 1 g the twists became larger leading edge
down with increasing Mach number (figs. 21 and 22). In all the maneu-
vers illustrated the right stabilizer, at both the tip and midsemispan,
was twisted more leading edge up than the left stabilizer.

The maximum stabilizer tip and midsemispan twists (fig. 16) were
$0.42°$ and $0.23°$ leading edge down, respectively, and occurred on the
left stabilizer at a normal acceleration near 1 g and at a Mach number
of 0.68. The maximum leading-edge-up twists (fig. 4) occurred on the
right stabilizer at a Mach number of 0.57 when the normal acceleration
was $2.9g$ and were $0.24°$ at the tip and $0.12°$ at the midsemispan.

The elevators have a built-in twist of $1.2°$ trailing edge up at
the tip, distributed parabolically from the root. The elevator twist
in flight increased trailing edge down with respect to the root as the

normal acceleration and down elevator loads increased. The largest twist (fig. 18) measured occurred on the left elevator and was 1.79^{o} trailing edge up.

Fuselage deflection.- The fuselage deflected down as the normal acceleration was increased. The bending moment on the fuselage due to fuselage mass and normal acceleration was apparently larger than the bending moment caused by the horizontal-tail load.

From figure 23 the variation of fuselage deflection at 1 g with measured horizontal-tail load can be seen. Each 1 g test point was determined at a different Mach number. At a pressure altitude close to 22,500 feet and at zero tail load the fuselage was deflected down 0.63 inches. Ground tests indicated that the fuselage deflects down as the skin temperature decreases. This accounts for the down fuselage deflection at zero tail load. The difference in slopes for the two altitudes is due to changes in fuselage skin temperature which occurred while the various runs were being made.

The maximum fuselage deflection (fig. 17) measured was 1.94 inches tail down with respect to the wing rear spar.

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1. Aiken, William S., Jr., and Wiener, Bernard: Time Histories of Horizontal-Tail Loads on a Jet-Powered Bomber Airplane in Four Maneuvers. NACA RM L9H16a, 1949.

2. Cooney, T. V., and McGowan, William A.: Time Histories of Loads and Deformations on a B-45A Airplane in Two Aileron Rolls. NACA RM L9I28a, 1949.

3. Cooney, T. V., and Aiken, William S., Jr.: Time Histories of the Loads and Deformations on the Horizontal Tail of a Jet-Powered Bomber Airplane in Accelerated Maneuvers at 30,000 Feet. NACA RM L50B24a, 1950.

4. McGowan, William A., and Wiener, Bernard: Time Histories of Horizontal-Tail Loads and Deformations on a Jet-Powered Bomber Airplane during Wind-Up Turns at 15,000 Feet and 22,500 Feet. NACA RM L50C21a, 1950.

TABLE I.- SUMMARY OF FLIGHT CONDITIONS

Figure	Airplane weight (lb)	Center-of-gravity position (percent M.A.C.)	Mach number	Elevator-trim-tab position, airplane nose up + nose down - (deg)	Power condition (percent maximum rpm)	Center-of-gravity normal-acceleration range (g units)	Pressure altitude (ft)
2	63,600	28.2	0.36	10.0	85	0.97 to 1.37	22,000
3	62,900	28.1	.45	7.0	85	.97 to 1.83	22,100
4	62,100	28.1	.57	2.8	88	.95 to 2.91	21,900
5	61,200	28.0	.62	1.0	90	.97 to 2.78	22,000
6	60,200	27.8	.67	0	96	.97 to 2.68	22,600
7	59,600	27.8	.71	-.2	96	.97 to 2.30	22,400
8	58,300	27.6	.72	-1.0	99	1.00 to 1.91	22,100
9	57,800	27.6	.75	-.2	100	1.00 to 1.37	22,300
10	56,000	27.4	.51	2.0	88	1.01 to 2.62	15,300
11	55,700	27.4	.54	0	92	.92 to 2.84	15,200
12	55,400	27.3	.56	0	92	.94 to 2.86	15,500
13	55,100	27.3	.60	-1.5	95	.94 to 2.77	14,700
14	54,800	27.2	.63	-2.3	95	.95 to 2.80	15,100
15	54,200	27.2	.65	-3.0	96	1.00 to 2.81	14,700
16	53,800	27.1	.68	-3.5	98	1.00 to 2.78	14,600
17	53,200	27.1	.70	-3.5	98	.91 to 2.72	15,600
18	52,900	27.1	.73	-3.5	100	1.00 to 2.29	14,400

Optigraph lights

43'10-3/8"

Optigraph camera

Twist bars

Optigraph camera

o Bending moment gages
× Shear gages
■ Torque gages

89'1/2"

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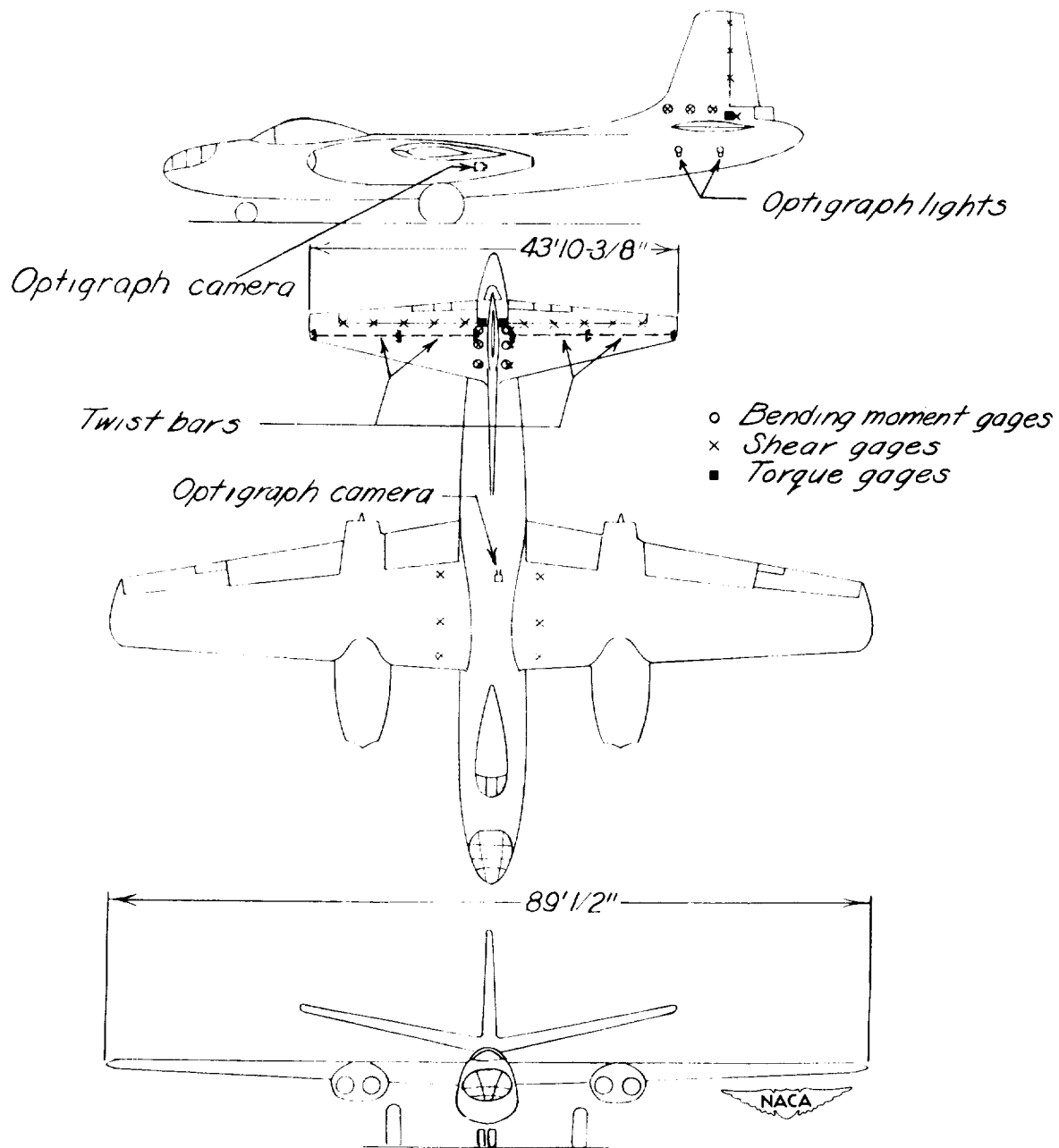
Figure 1.- Three-view drawing of test airplane showing approximate
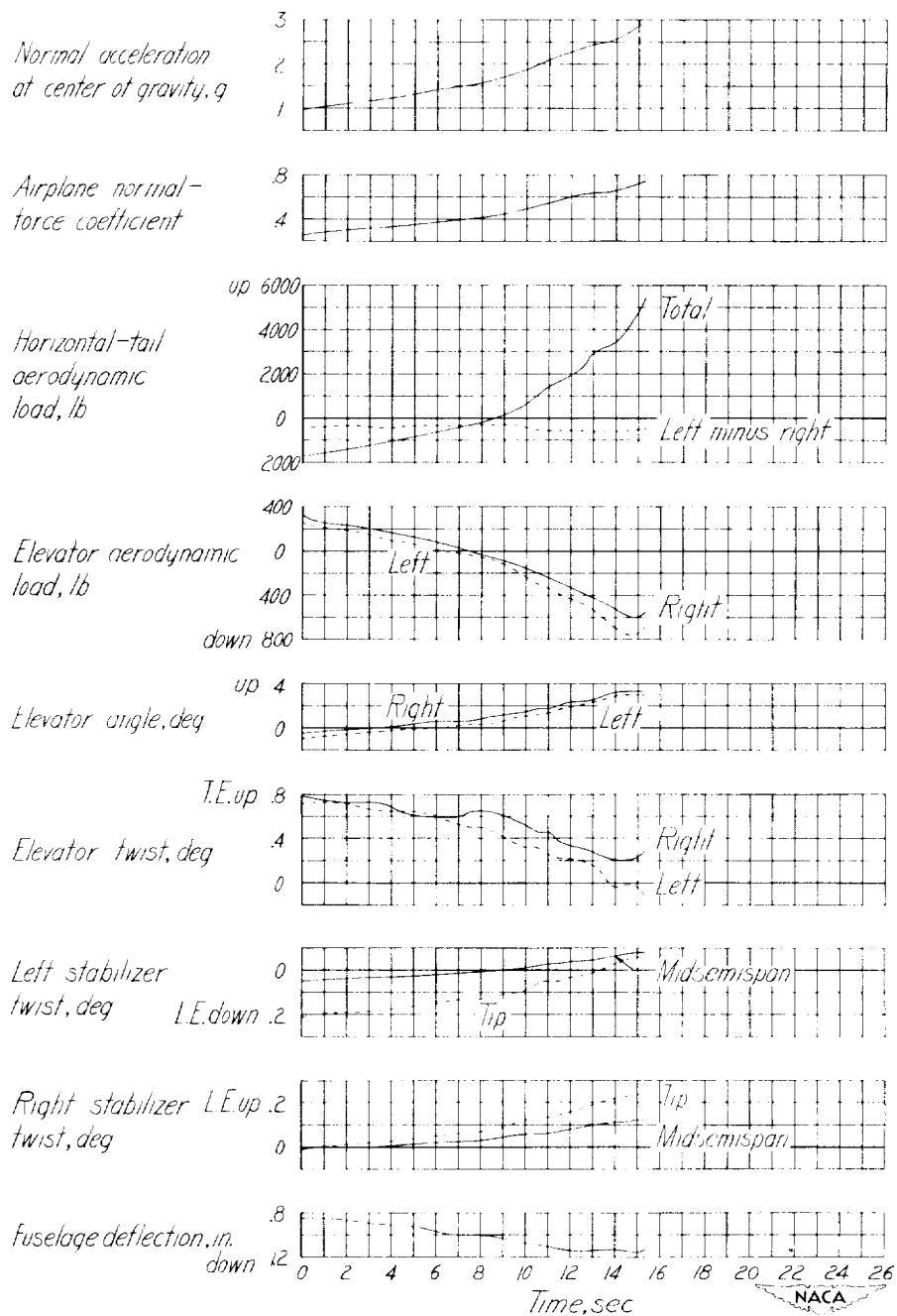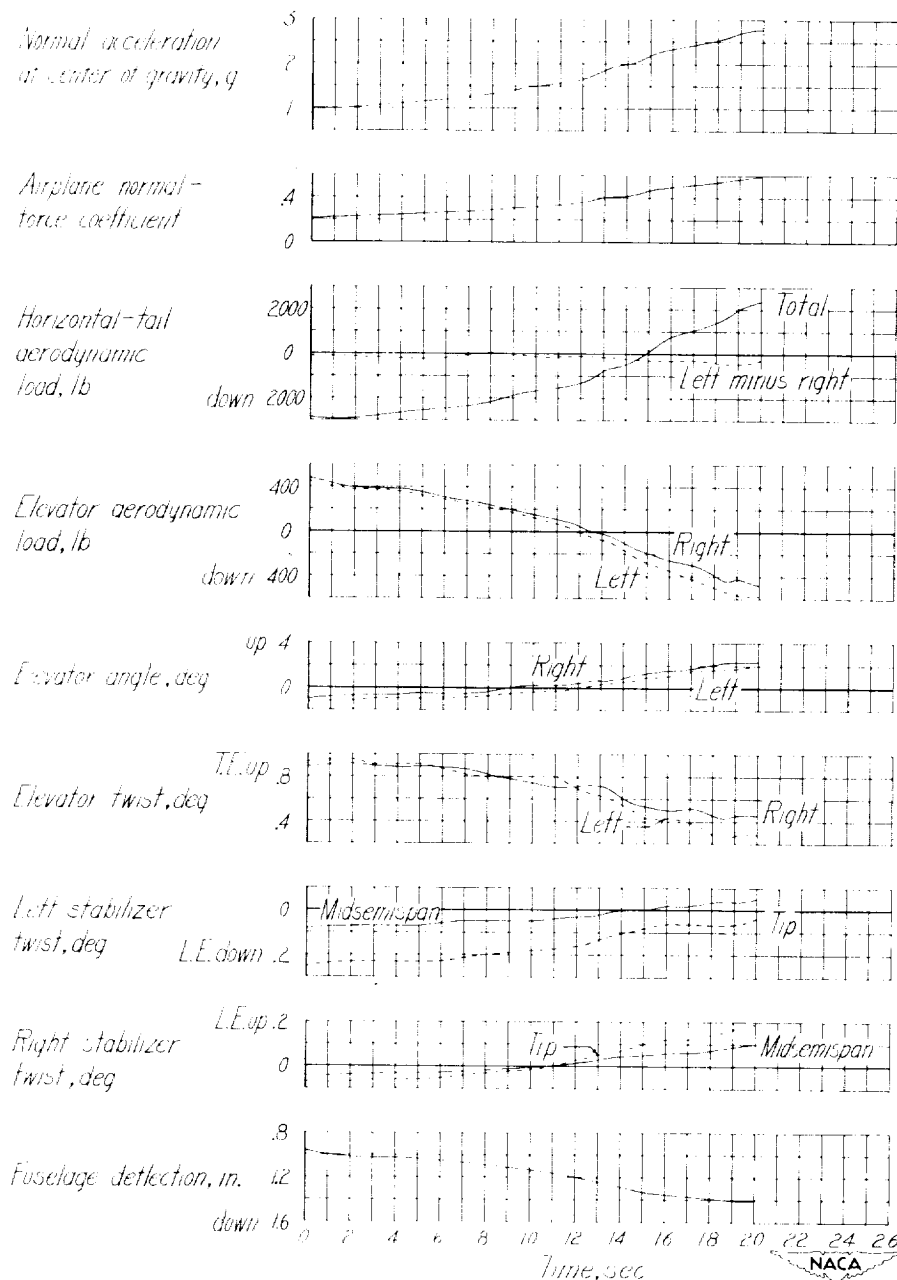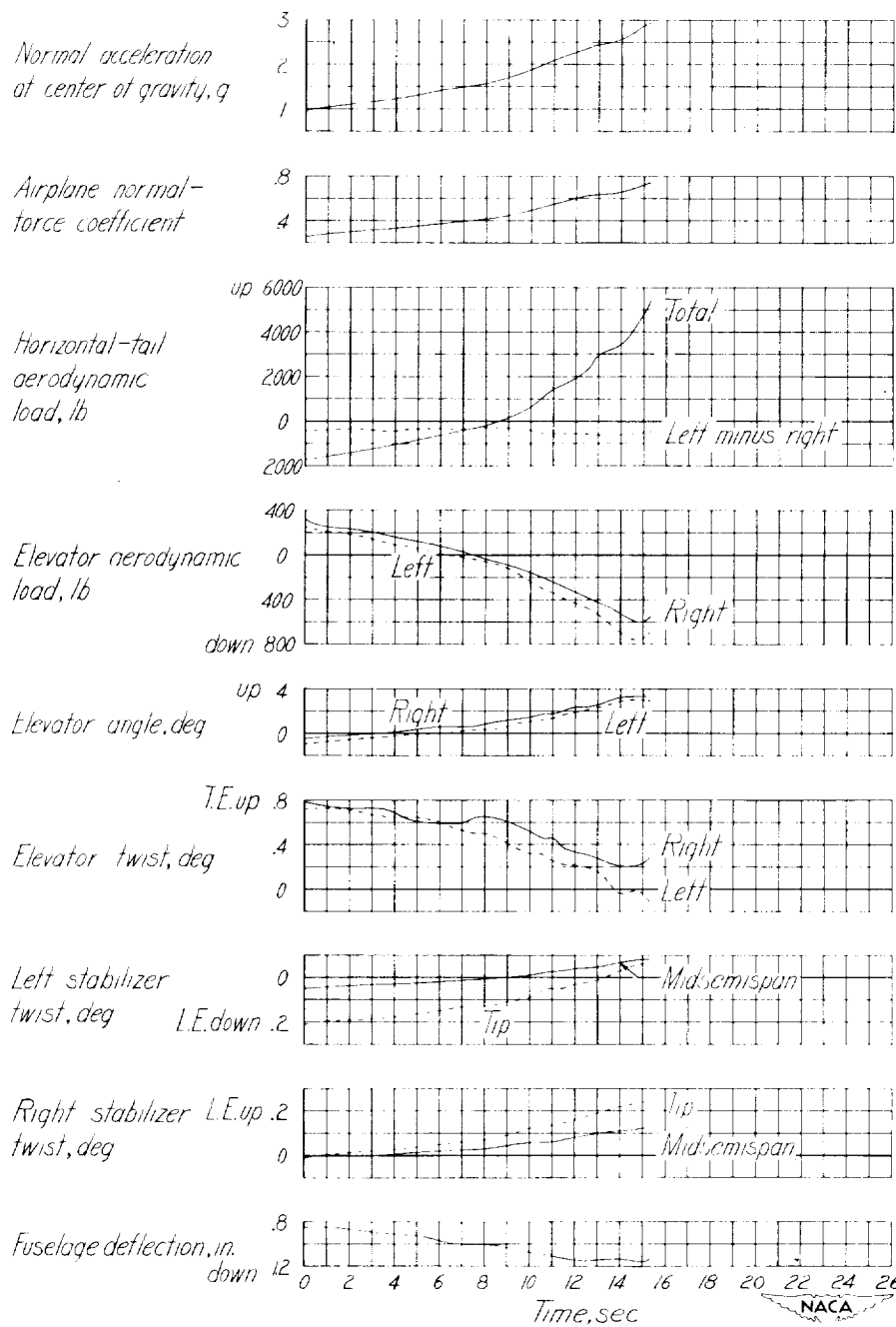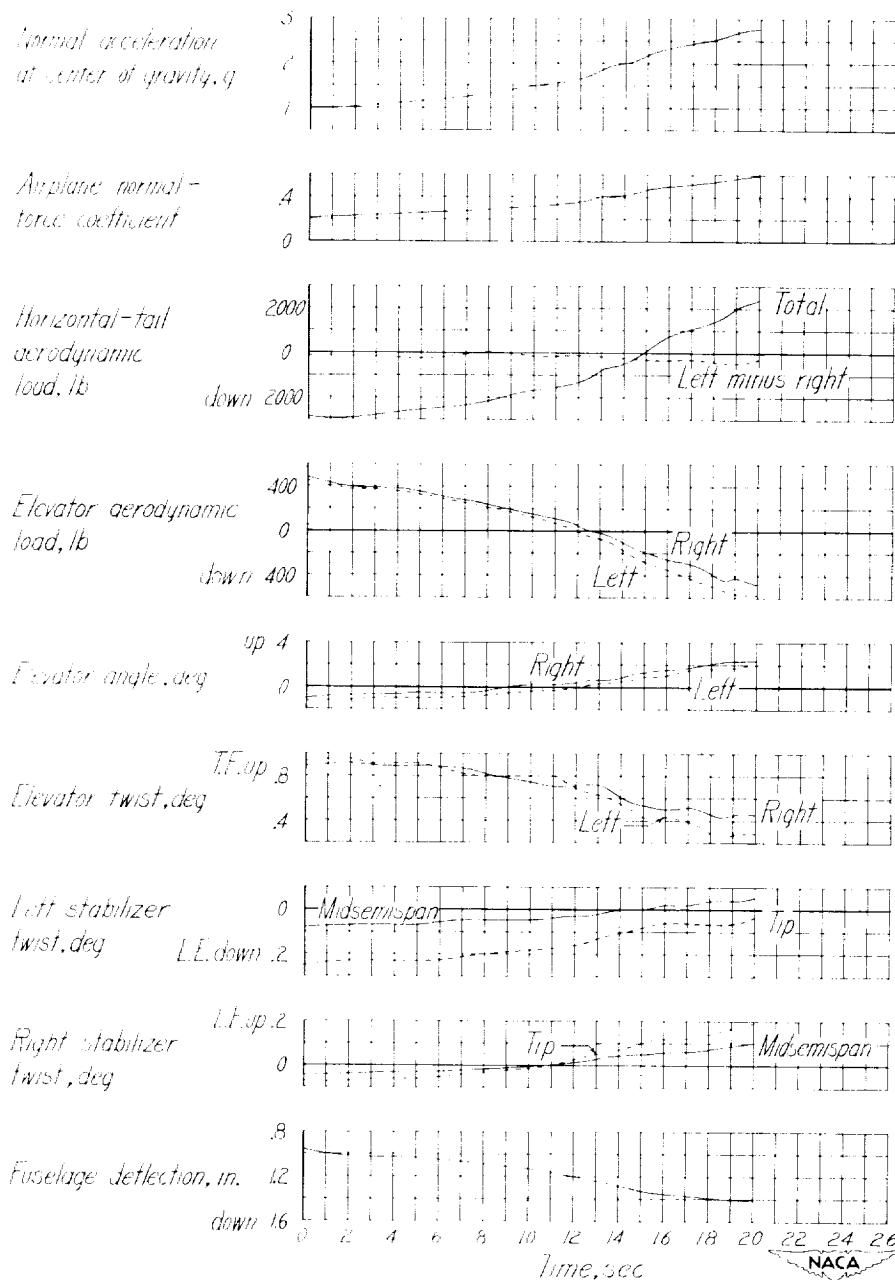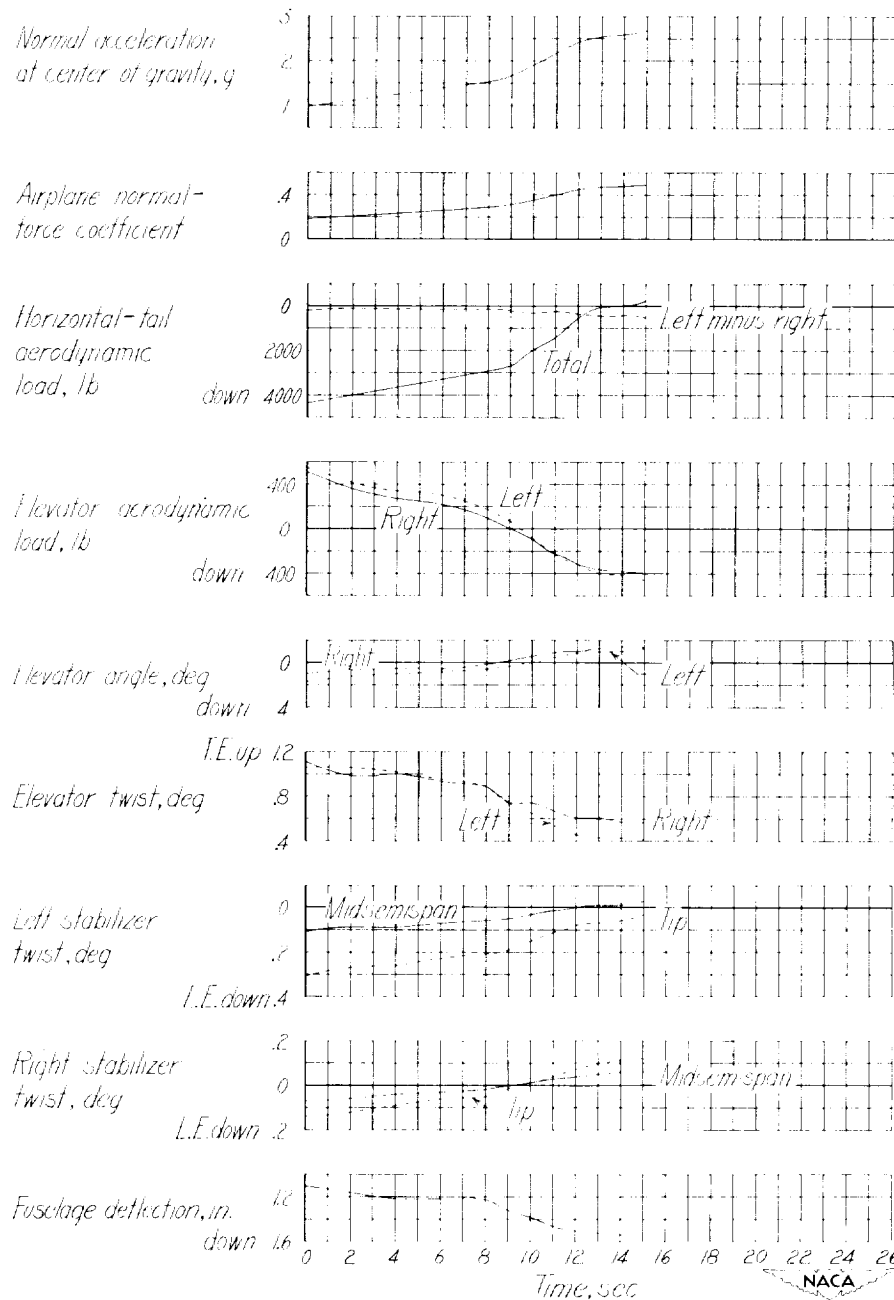locations of strain-gage bridges and deflection-measuring devices.
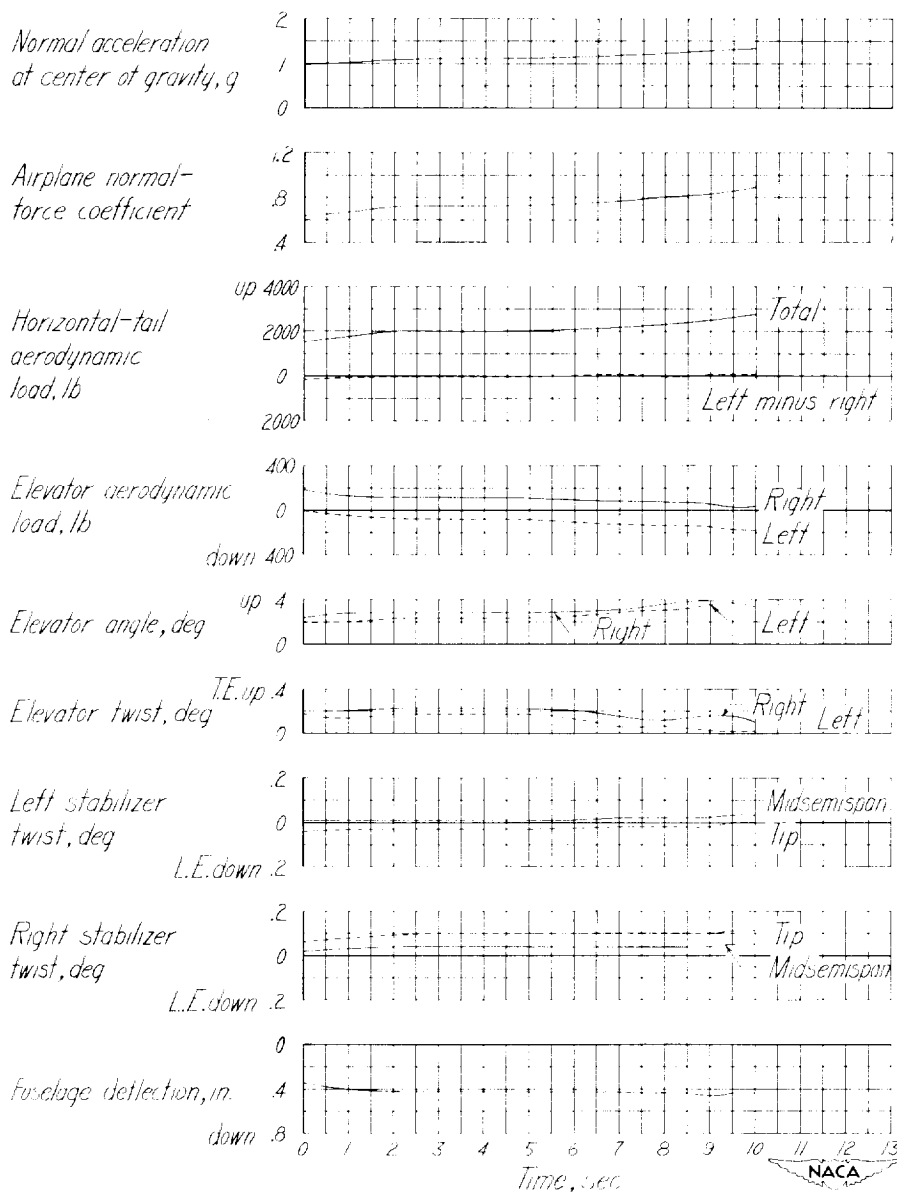
Figure 2.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 22,000 feet; Mach number, 0.36; airplane weight,
63,600 pounds; center of gravity is at 28.2 percent mean aerodynamic
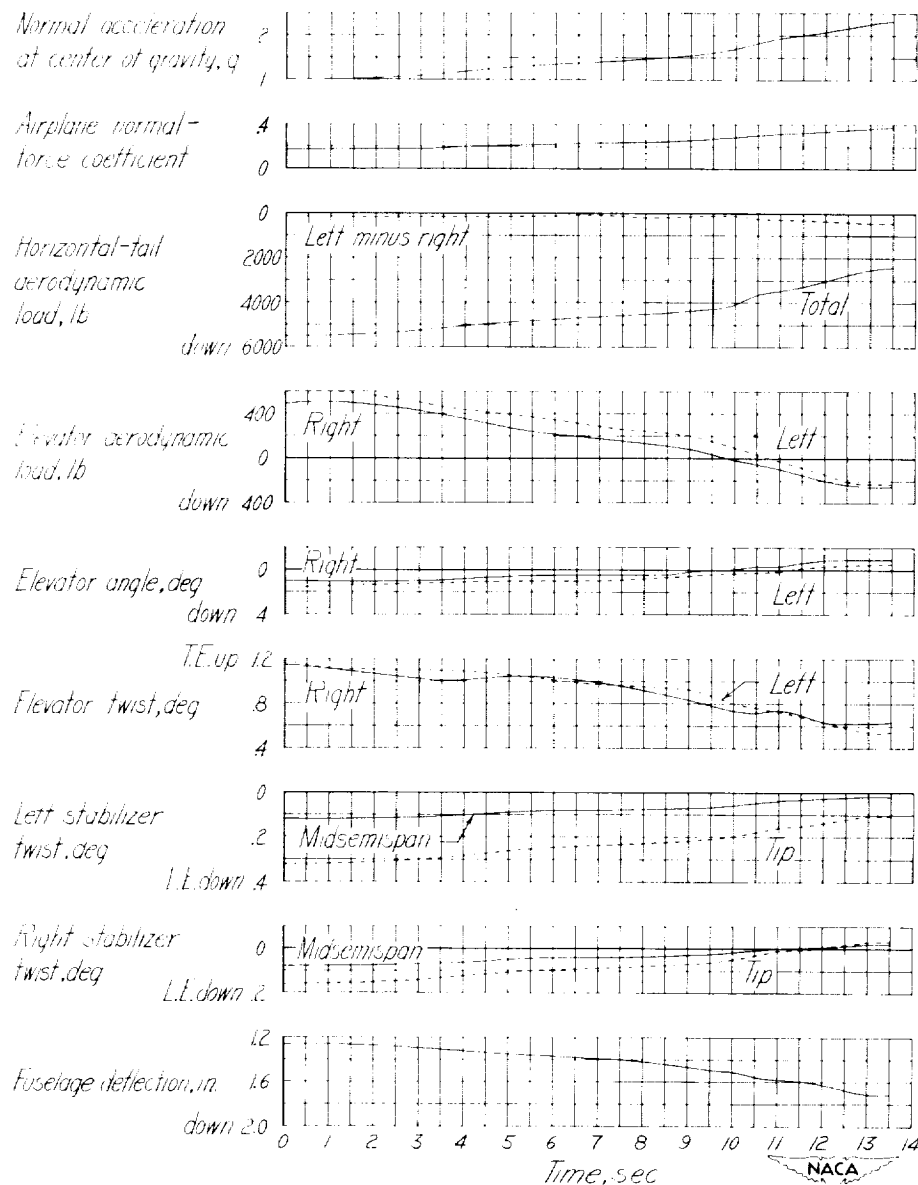chord; elevator trim tabs, 10.0° airplane nose up.
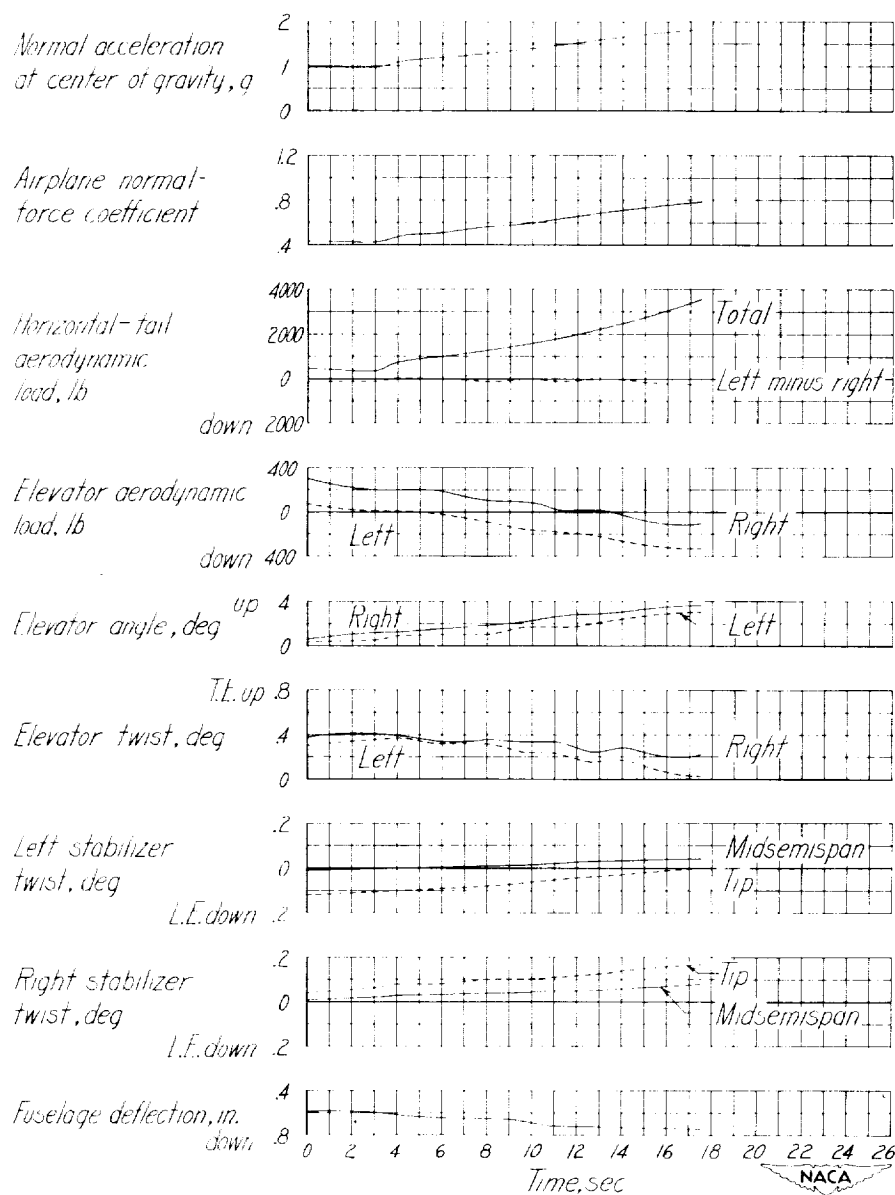
Figure 3.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,100 feet; Mach number, 0.45; airplane weight, 62,900 pounds; center of gravity is at 28.1 percent mean aerodynamic chord; elevator trim tabs, 7.0° airplane nose up.

Figure 4.- Time histories of various quantities during a wind-up turn. Pressure altitude, 21,900 feet; Mach number, 0.57; airplane weight, 62,100 pounds; center of gravity is at 28.1 percent mean aerodynamic chord; elevator trim tabs, 2.8° airplane nose up.
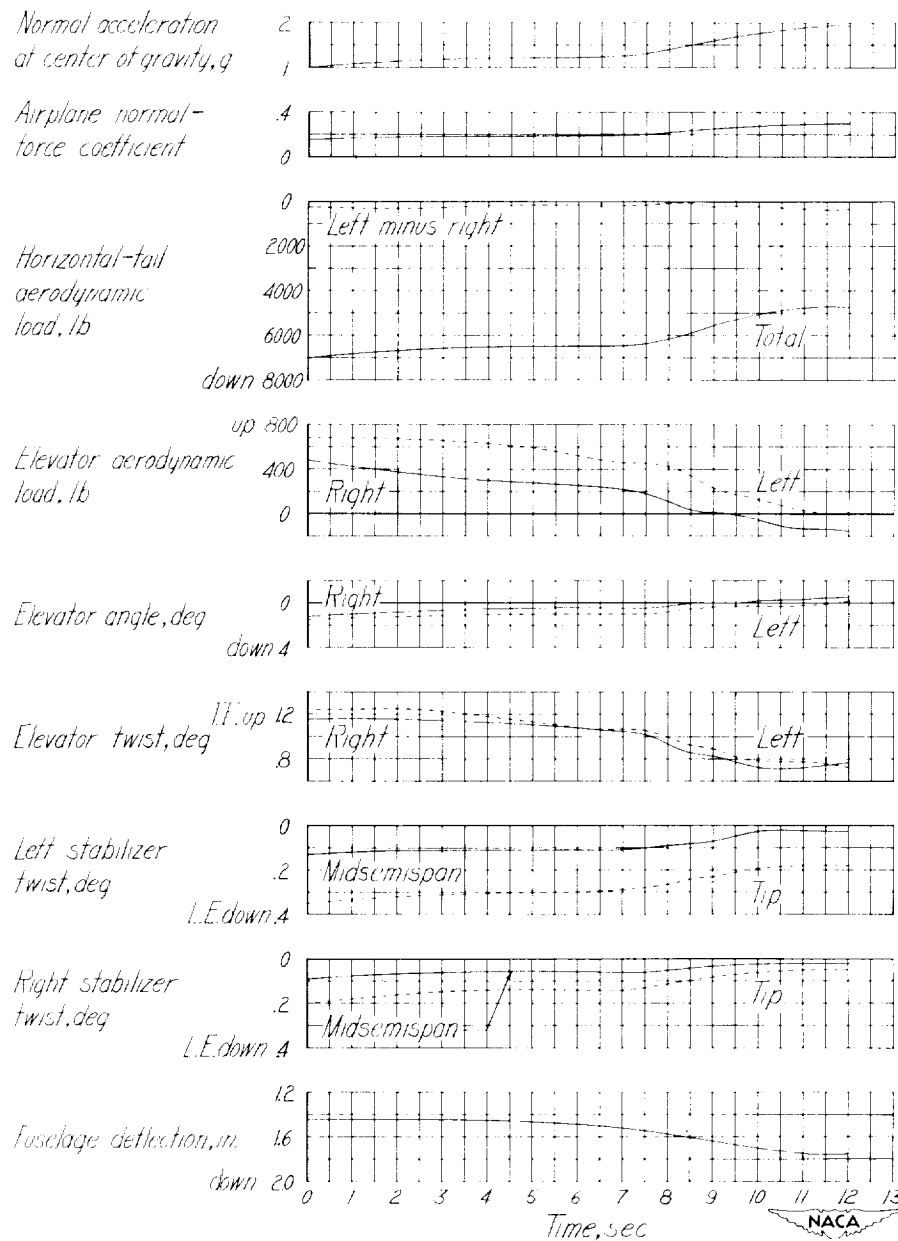
Figure 5.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,000 feet; Mach number, 0.62; airplane weight, 61,200 pounds; center of gravity is at 28.0 percent mean aerodynamic chord; elevator trim tabs, 1.0° airplane nose up.
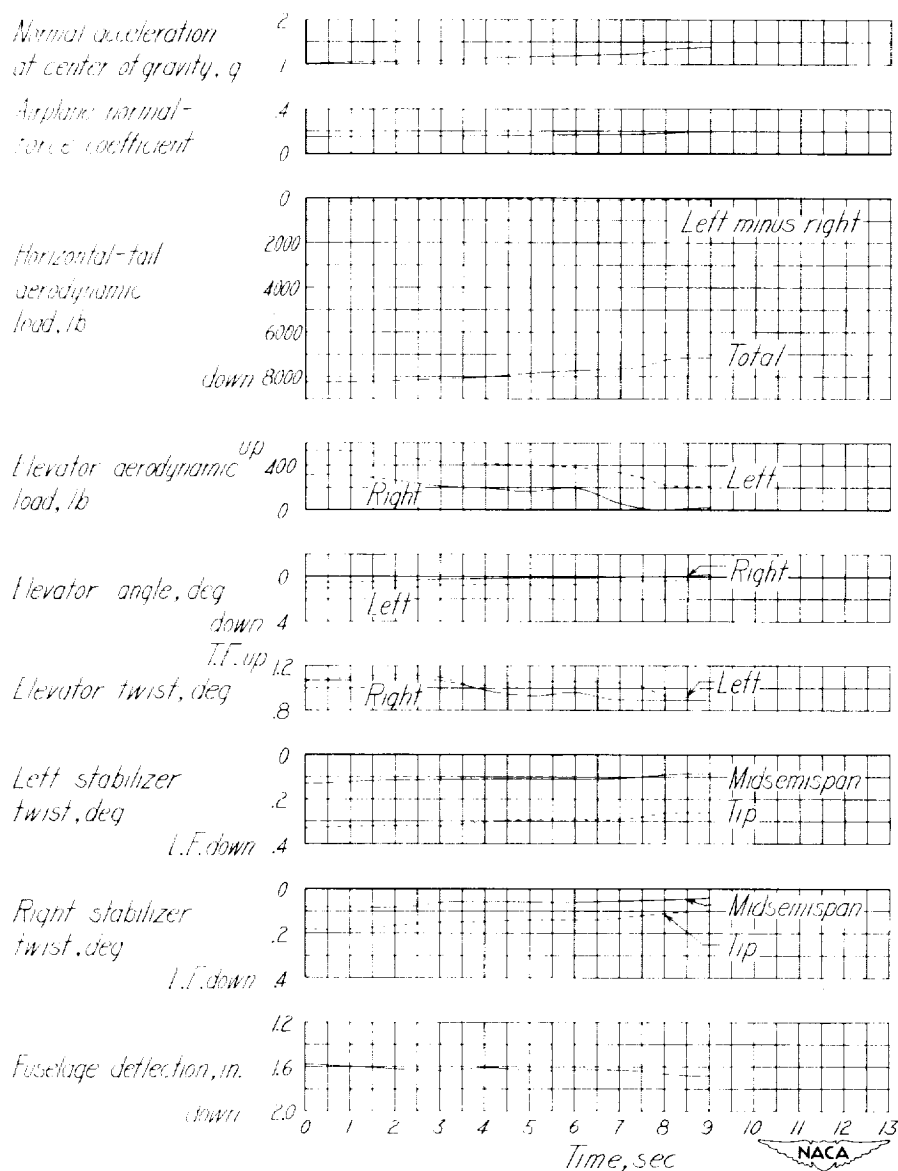
Figure 4.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 21,900 feet; Mach number, 0.57; airplane weight,
62,100 pounds; center of gravity is at 28.1 percent mean aerodynamic
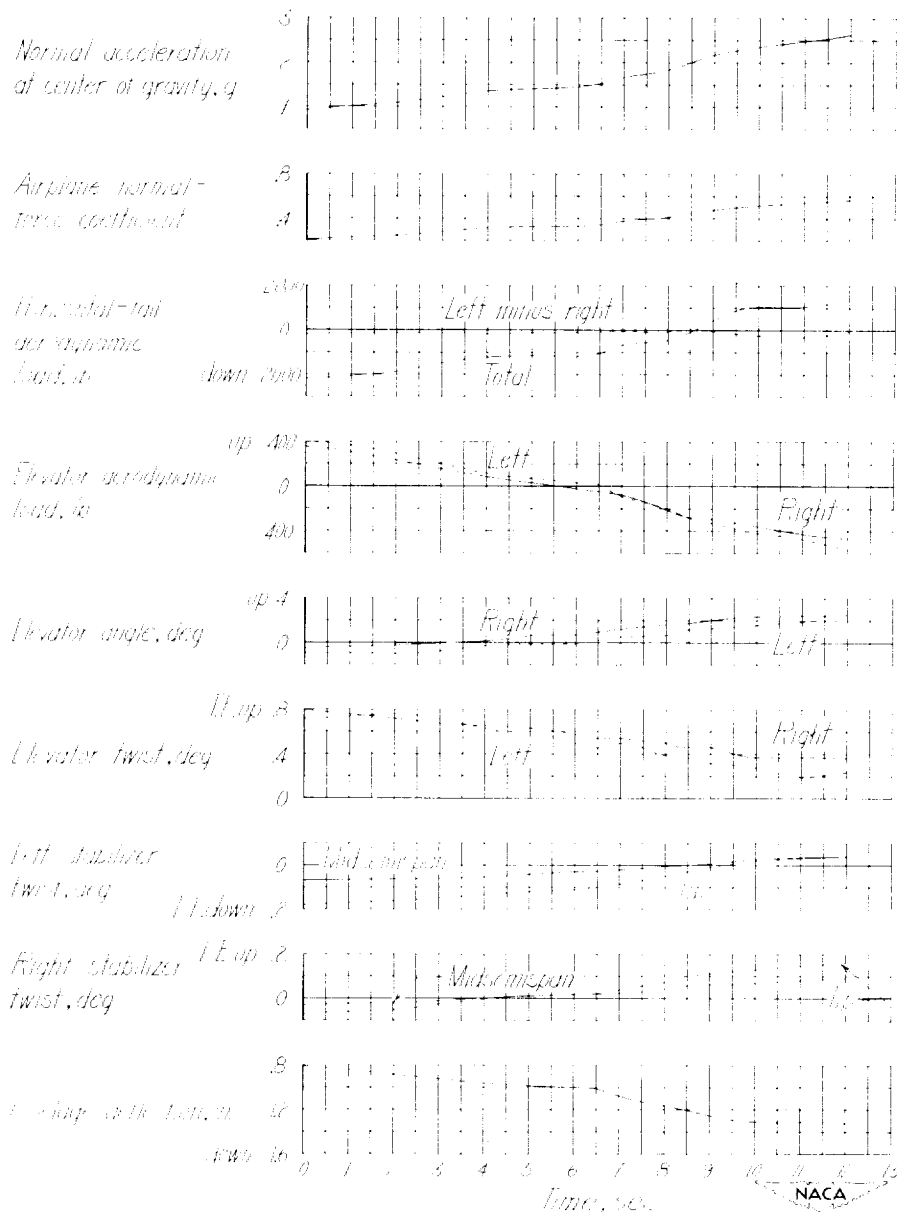chord; elevator trim tabs, 2.8° airplane nose up.

Figure 5.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 22,000 feet; Mach number, 0.62; airplane weight,
61,200 pounds; center of gravity is at 28.0 percent mean aerodynamic
chord; elevator trim tabs, 1.0° airplane nose up.

Figure 6.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,600 feet; Mach number, 0.67; airplane weight, 60,200 pounds; center of gravity is at 27.8 percent mean aerodynamic chord; elevator trim tabs, 0.0° airplane nose up.
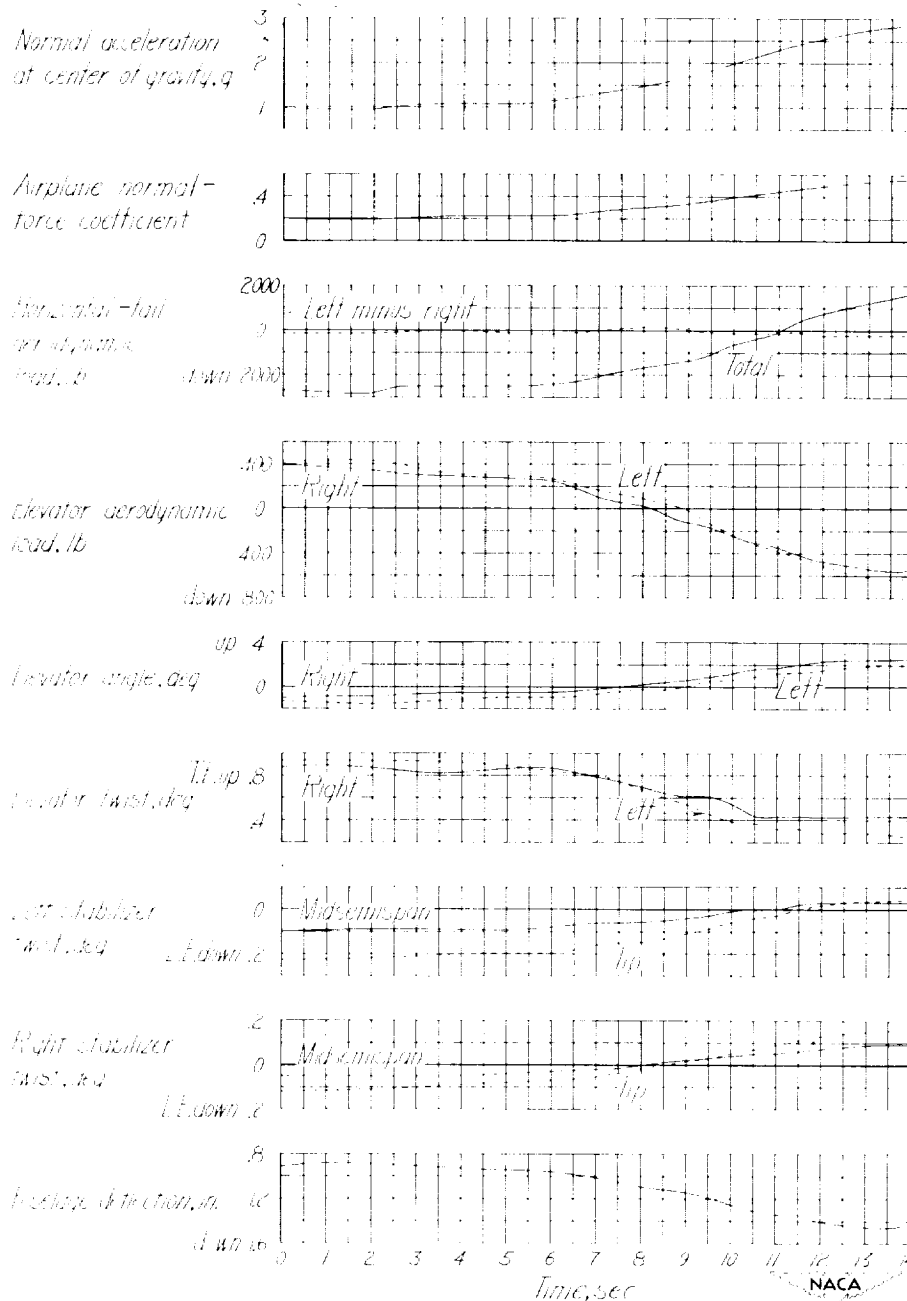
Figure 7.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,400 feet; Mach number, 0.71; airplane weight, 59,600 pounds; center of gravity is at 27.8 percent mean aerodynamic chord; elevator trim tabs, 0.2° airplane nose down.
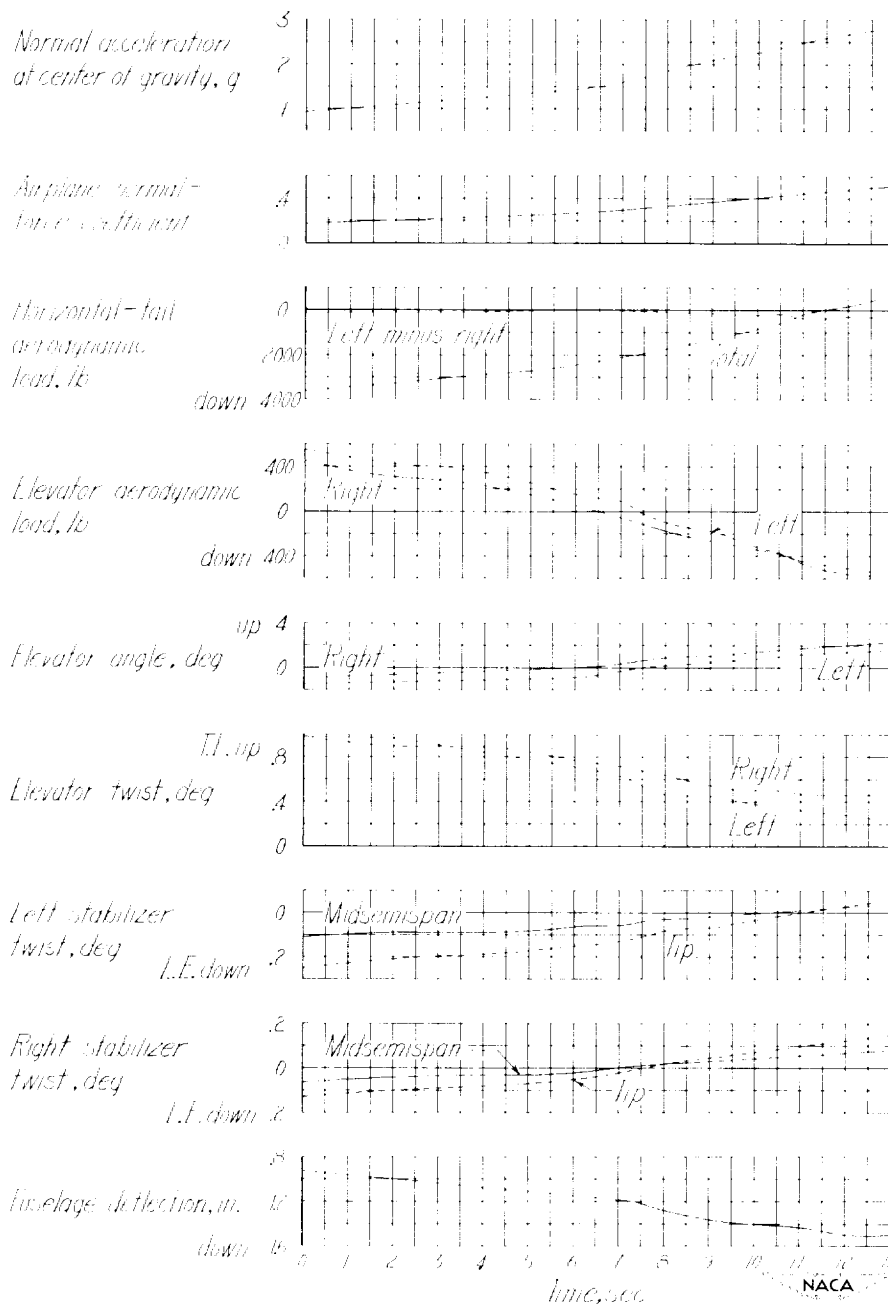
Figure 8.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,100 feet; Mach number, 0.72; airplane weight, 58,300 pounds; center of gravity is at 27.6 percent mean aerodynamic chord; elevator trim tabs, 1.0° airplane nose down.
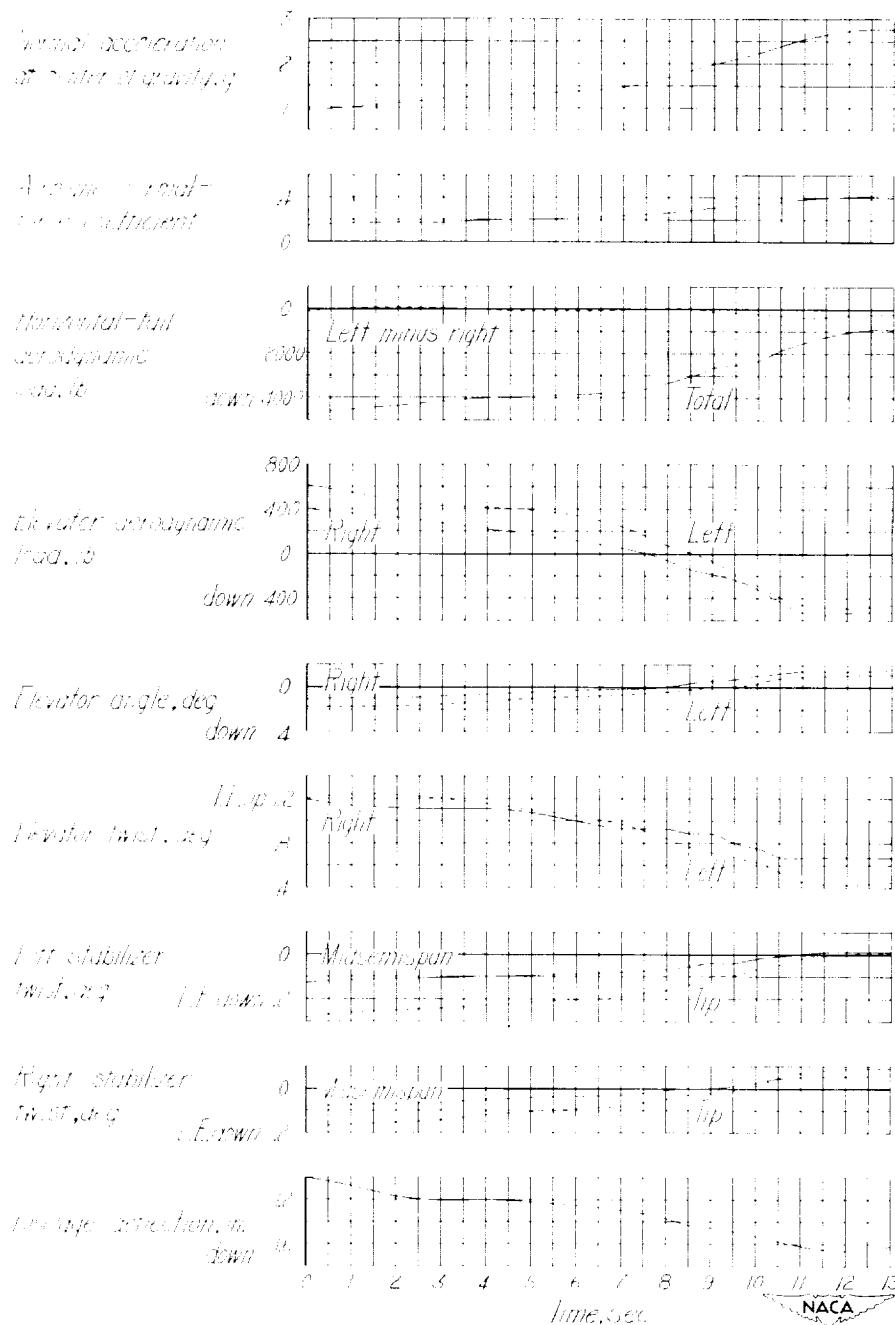
Figure 9.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 22,300 feet; Mach number, 0.75; airplane weight,
57,800 pounds; center of gravity is at 27.6 percent mean aerodynamic
chord; elevator trim tabs, 0.2° airplane nose down.

Figure 10.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 15,300 feet; Mach number, 0.51; airplane weight,
56,000 pounds; center of gravity is at 27.4 percent mean aerodynamic
chord; elevator trim tabs, 2.0° airplane nose up.

Figure 11.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 15,200 feet; Mach number, 0.54; airplane weight,
55,700 pounds; center of gravity is at 27.4 percent mean aerodynamic
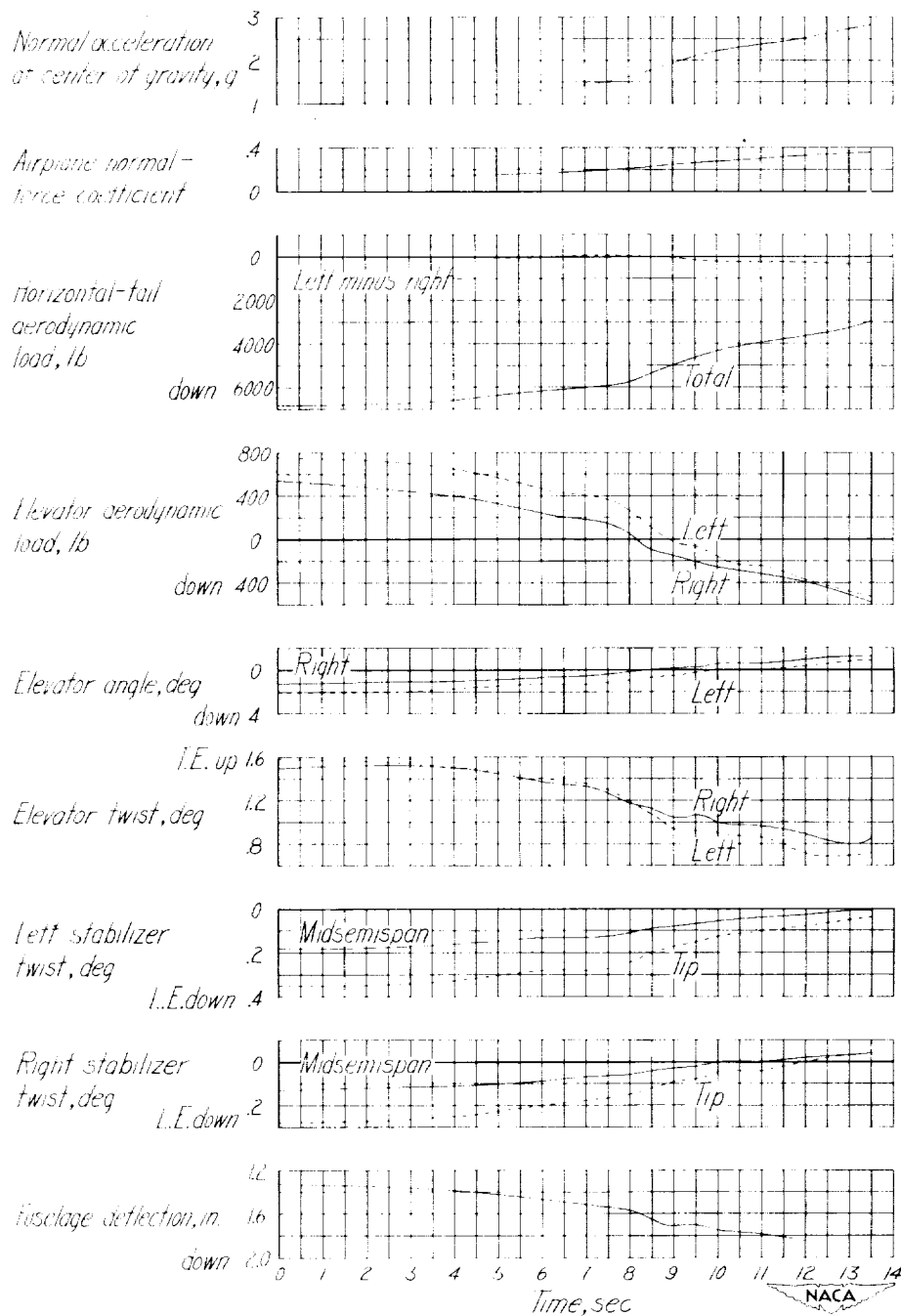chord; elevator trim tabs, 0.0° airplane nose up.

Figure 12.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,500 feet; Mach number, 0.56; airplane weight, 55,400 pounds; center of gravity is at 27.3 percent mean aerodynamic chord; elevator trim tabs, 0.0° airplane nose up.
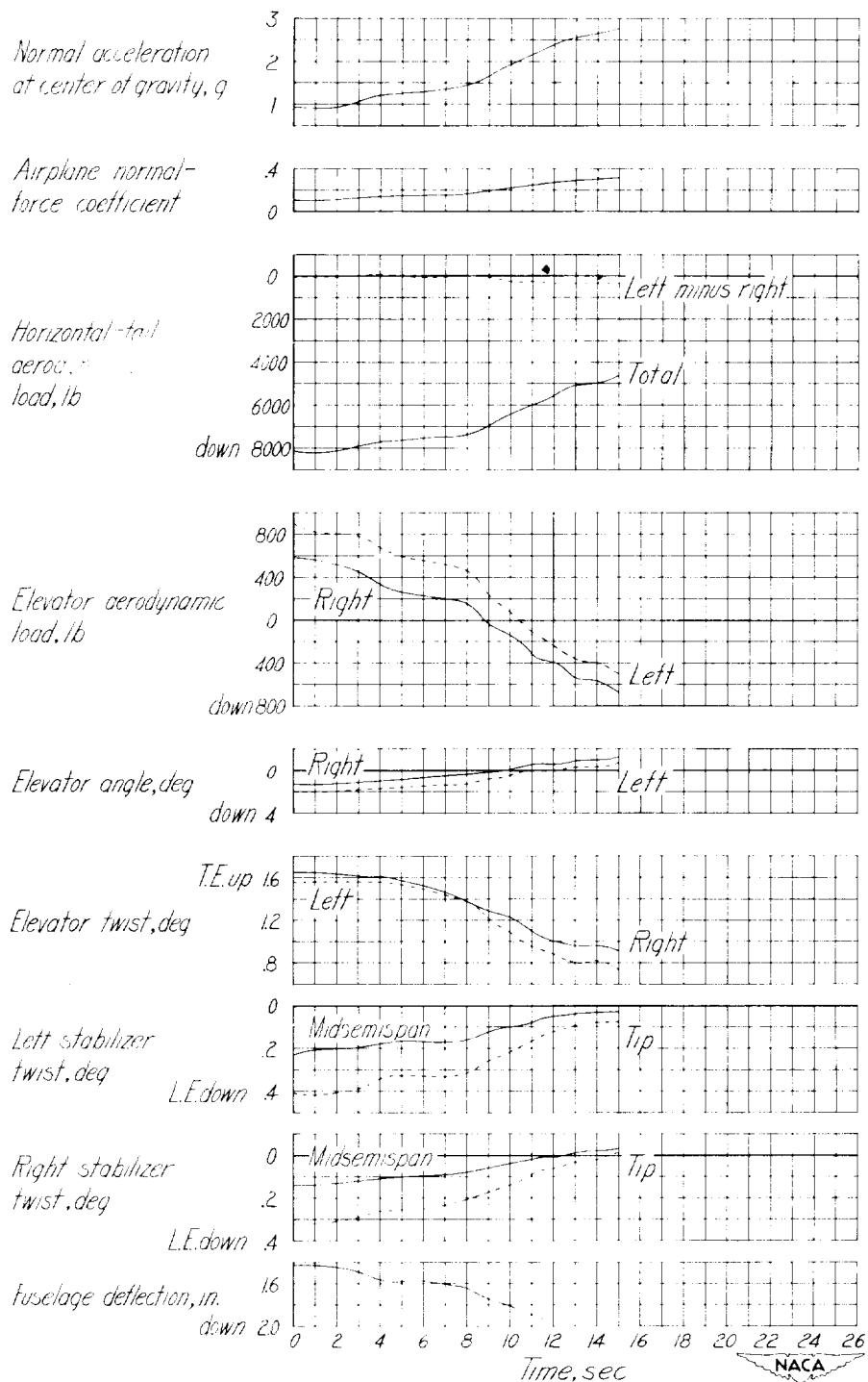
Figure 13.- Time histories of various quantities during a wind-up turn. Pressure altitude, 14,700 feet; Mach number, 0.60; airplane weight, 55,100 pounds; center of gravity is at 27.3 percent mean aerodynamic chord; elevator trim tabs, 1.5° airplane nose down.
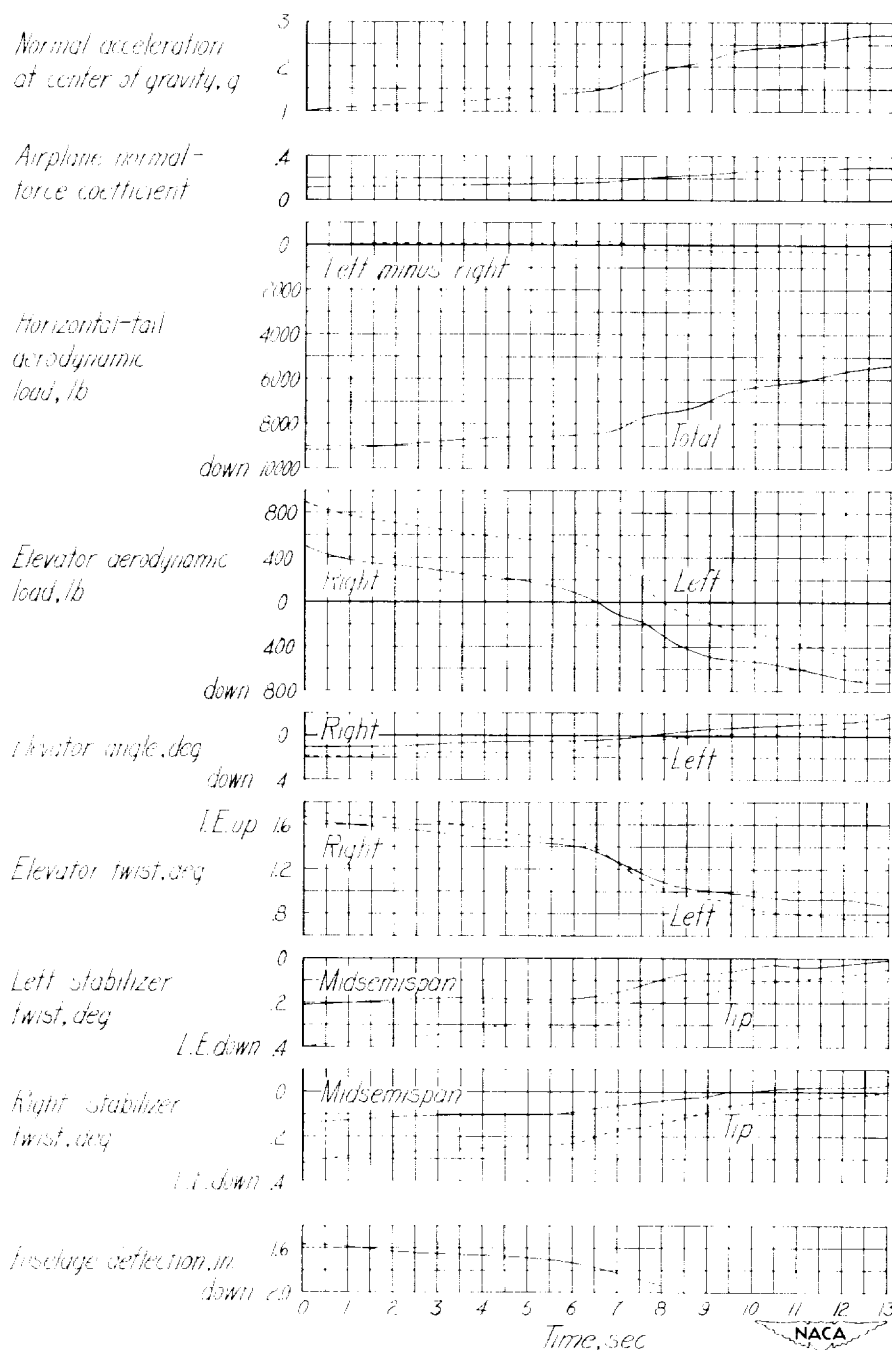
Figure 14.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,100 feet; Mach number, 0.63; airplane weight, 54,800 pounds; center of gravity is at 27.2 percent mean aerodynamic chord; elevator trim tabs, 2.3° airplane nose down.

CONFIDENTIAL

Figure 15.- Time histories of various quantities during a wind-up turn. Pressure altitude, 14,700 feet; Mach number, 0.65; airplane weight, 54,200 pounds; center of gravity is at 27.2 percent mean aerodynamic chord; elevator trim tabs, 3.0° airplane nose down.
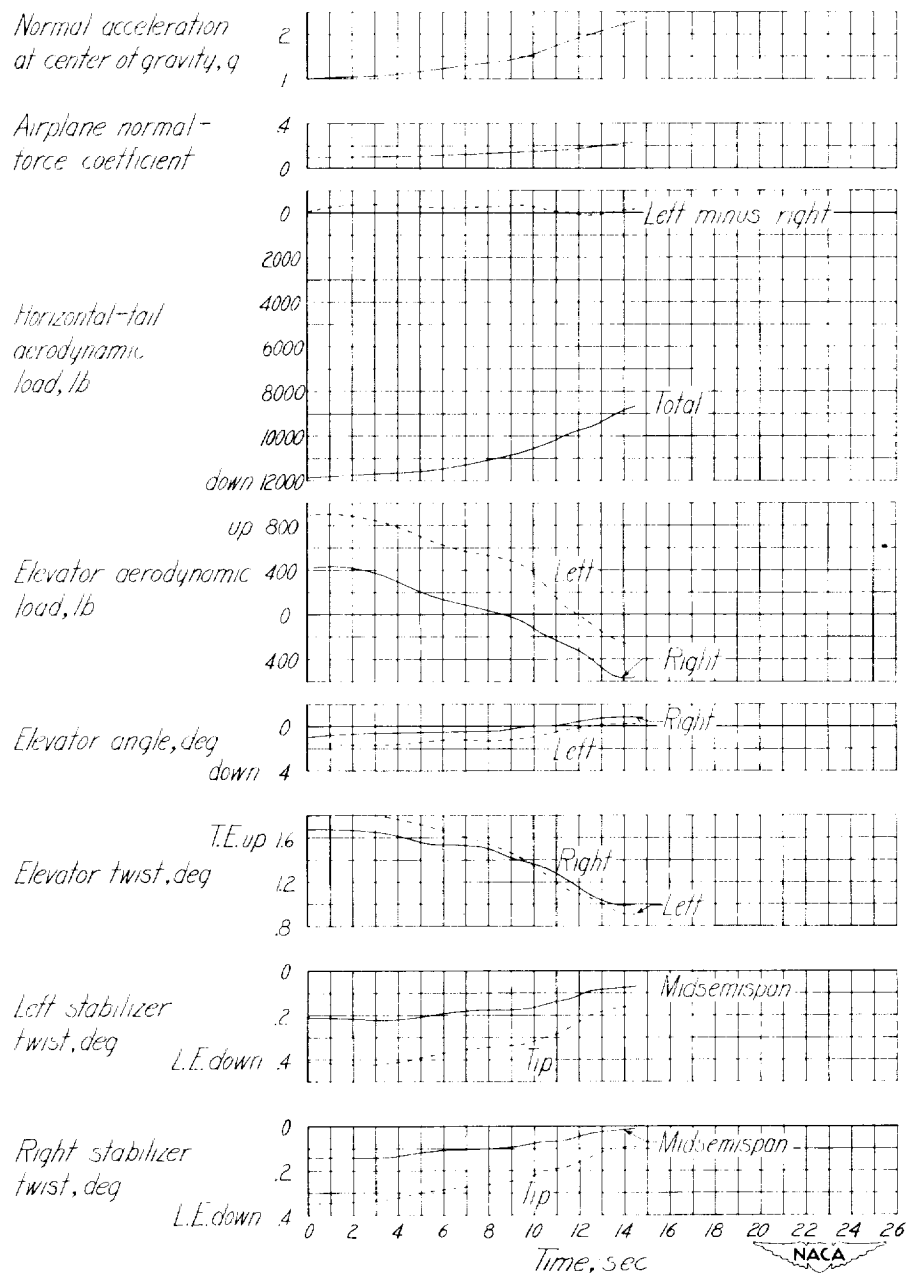
CONFIDENTIAL

Figure 16.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 14,600 feet; Mach number, 0.68; airplane weight,
53,800 pounds; center of gravity is at 27.1 percent mean aerodynamic
chord; elevator trim tabs, 3.5° airplane nose down.

Figure 17.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,600 feet; Mach number, 0.70; airplane weight, 53,200 pounds; center of gravity is at 27.1 percent mean aerodynamic chord; elevator trim tabs, 3.5° airplane nose down.

Figure 18.- Time histories of various quantities during a wind-up turn.
Pressure altitude, 14,400 feet; Mach number, 0.73; airplane weight,
52,900 pounds; center of gravity is at 27.1 percent mean aerodynamic
chord; elevator trim tabs, 3.5° airplane nose down.
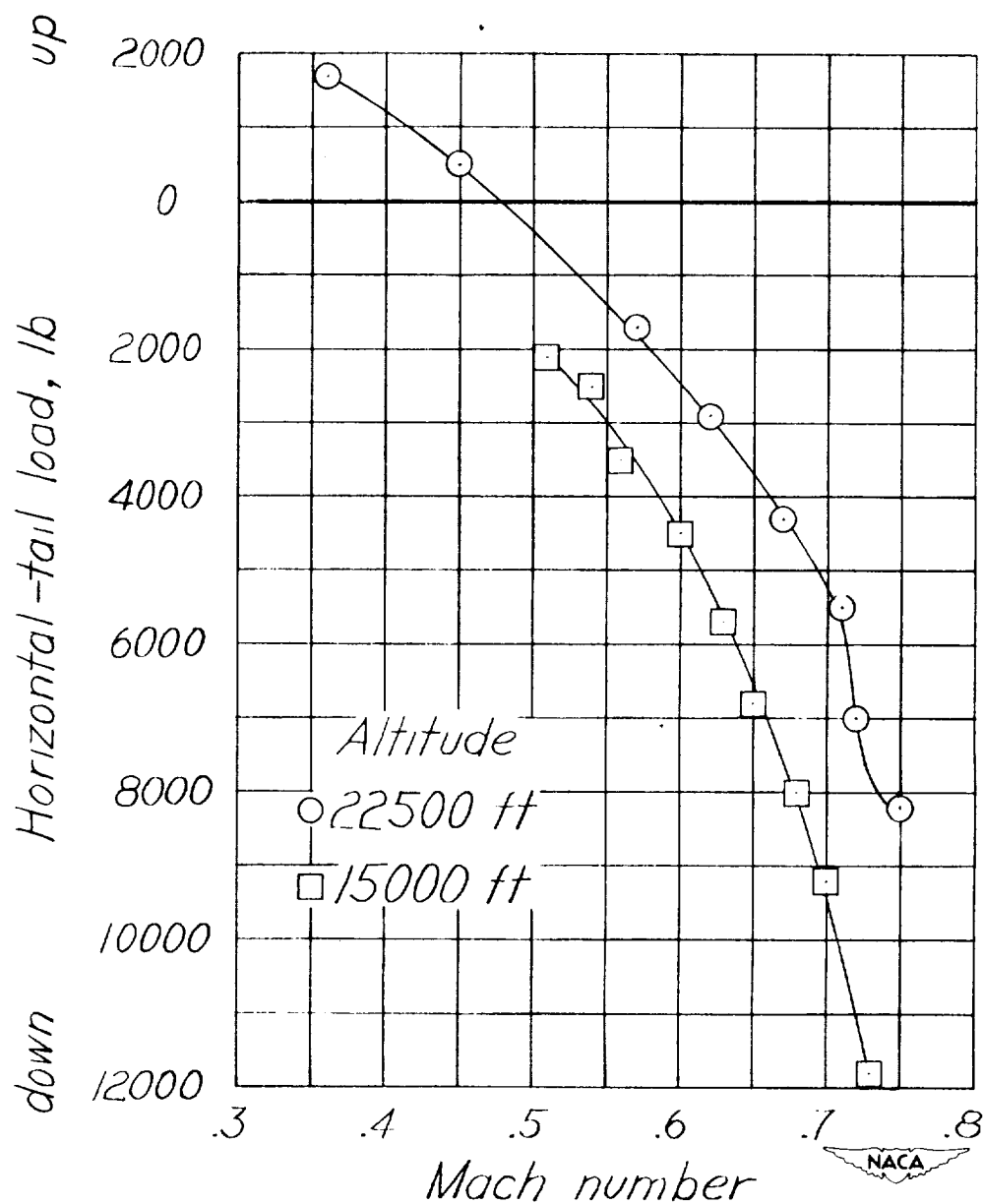
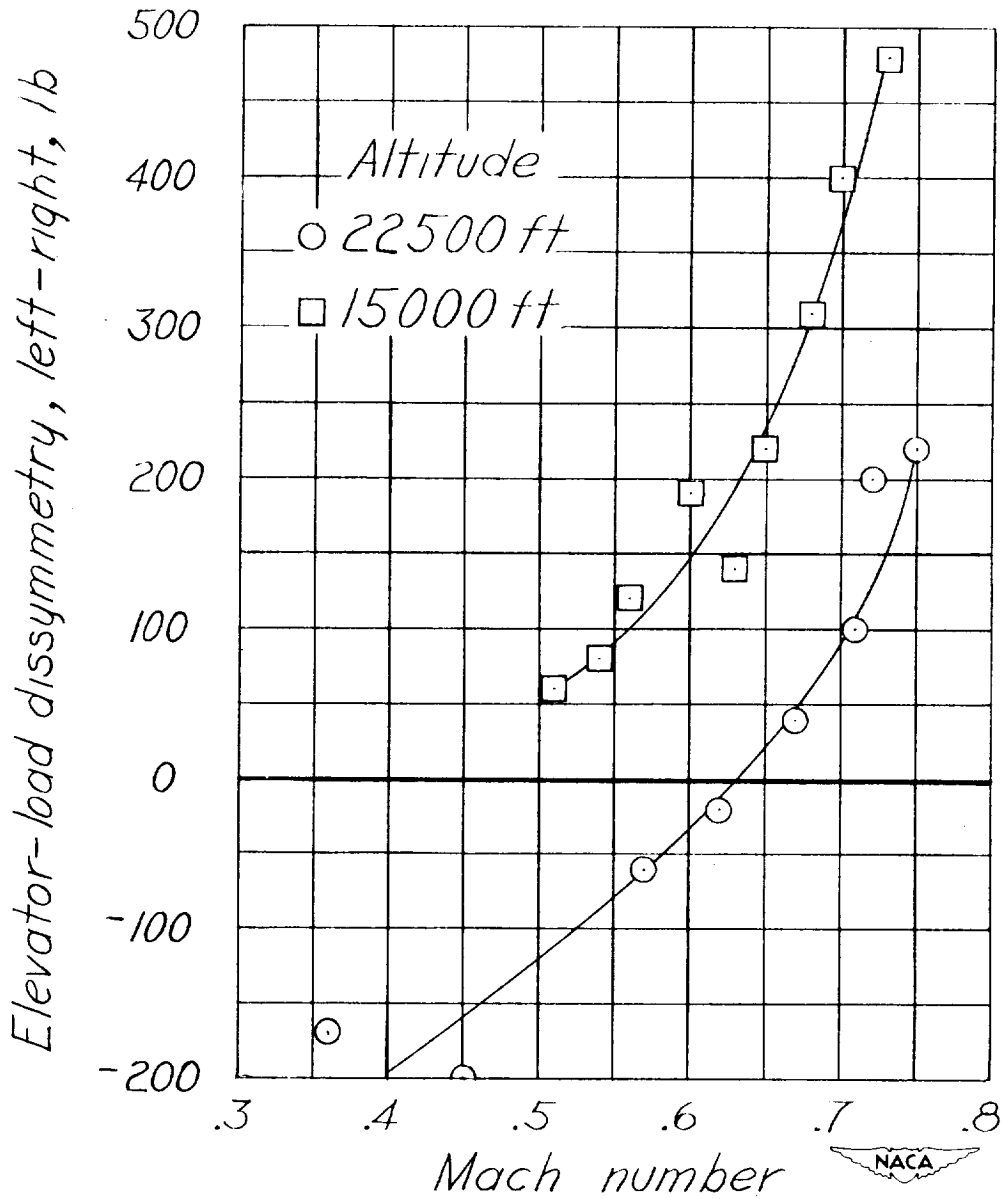Figure 19.- Variation of horizontal-tail load with Mach number. Normal acceleration 1 g.

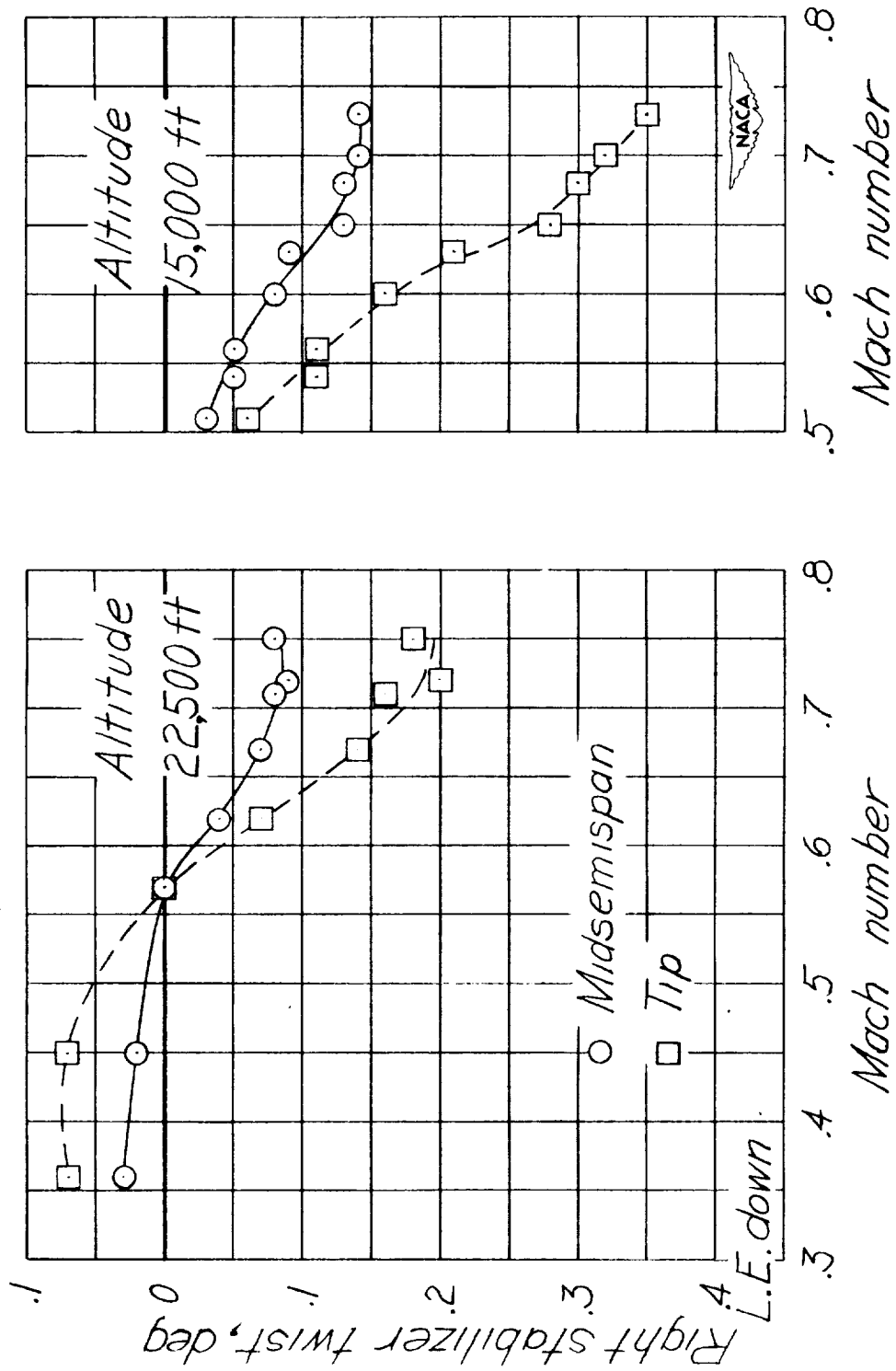Figure 20.- Variation of elevator-load dissymmetry with Mach number.
Normal acceleration 1 g.

Figure 21.- Right stabilizer tip and midsemispan twist variation with Mach number. Normal acceleration 1 g.
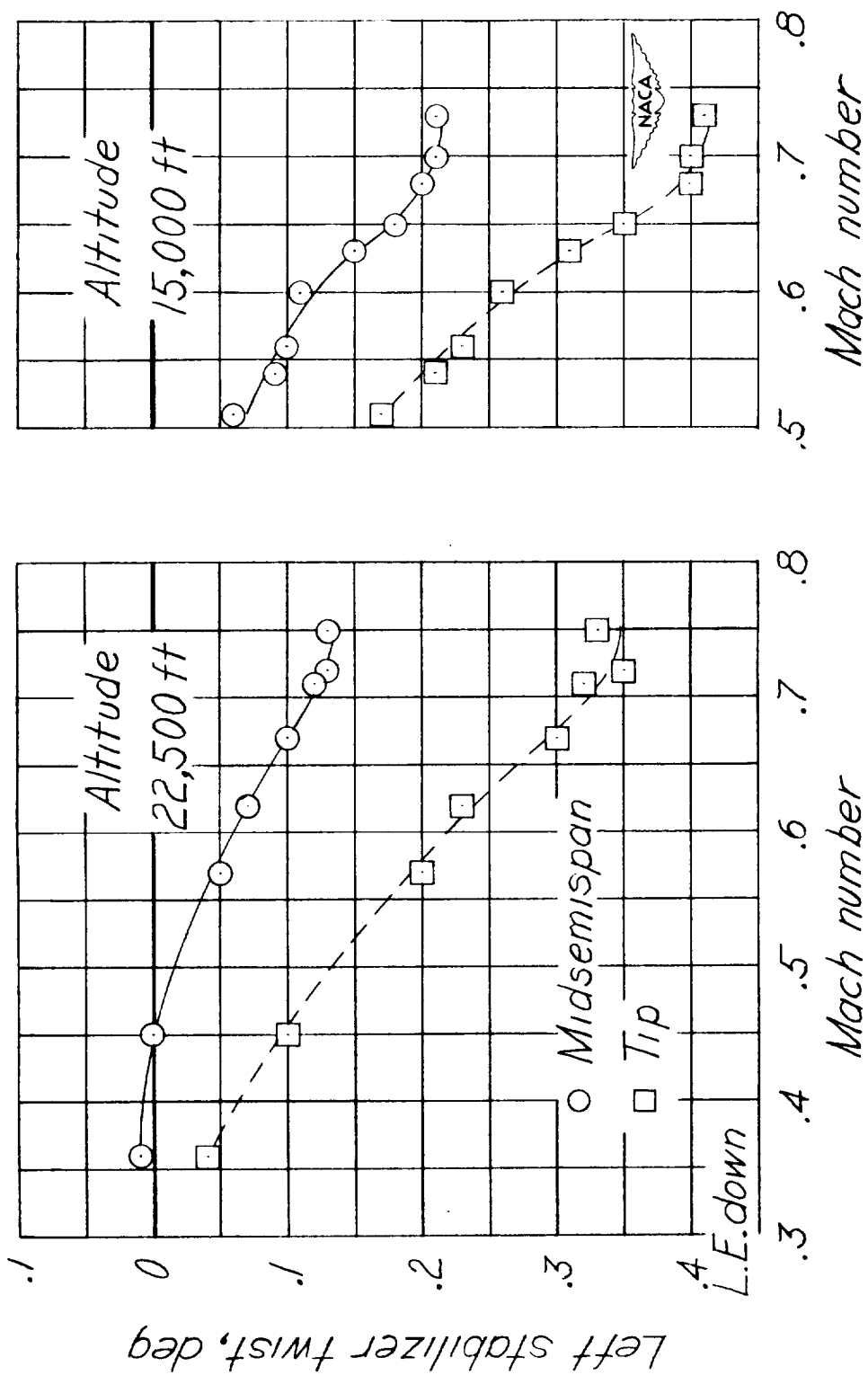
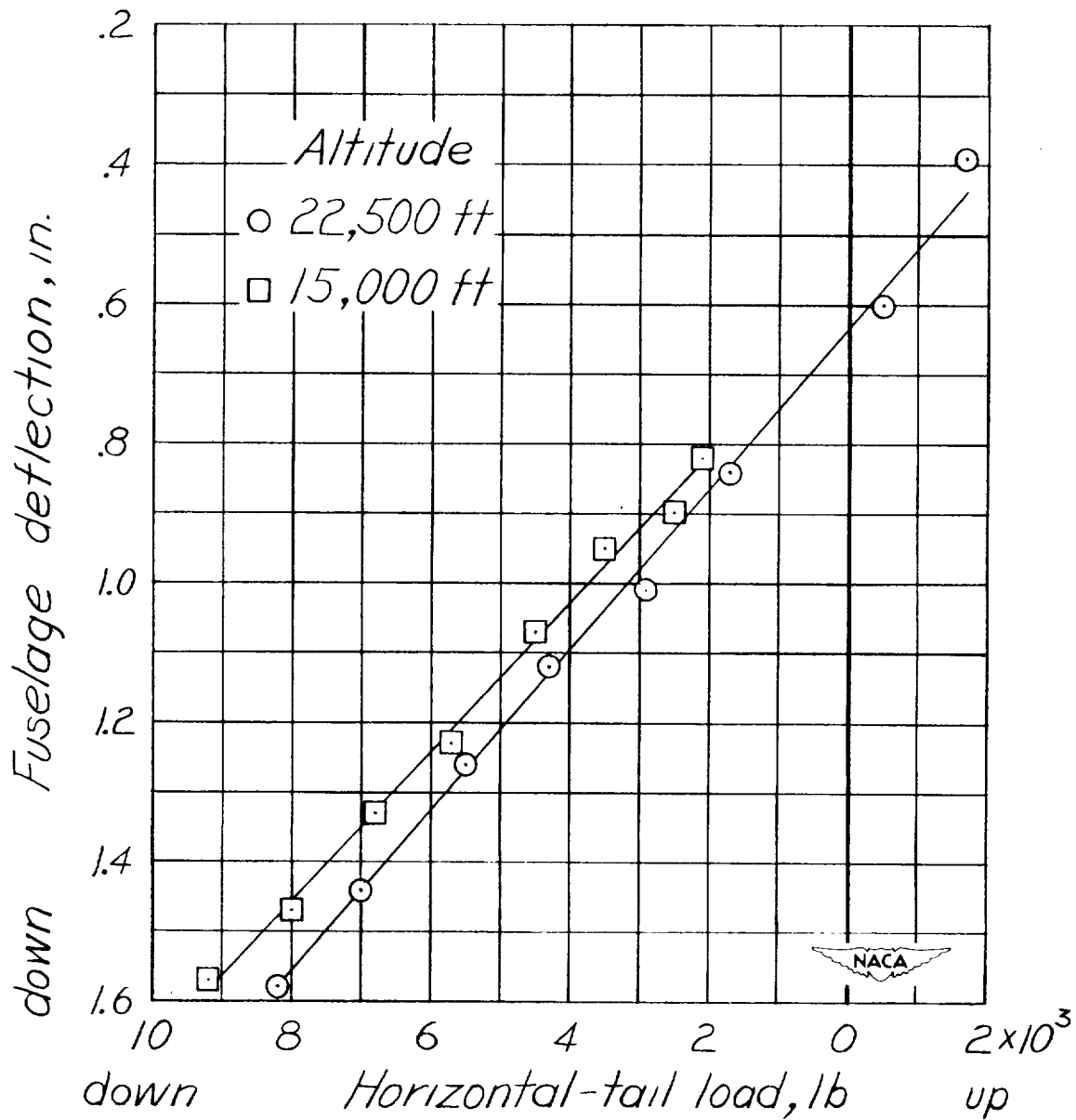Figure 22.- Left stabilizer tip and midsemispan twist variation with Mach number. Normal acceleration 1 g.

Figure 23.- Fuselage-deflection variation with horizontal-tail load.
Normal acceleration 1 g.